

REMARKS

Claims 1, 4-5, 10, 12-13, and 27-28 have been amended.

Claim 33 has been canceled.

Claims 34 and 35 have been added.

Claim 34 has been withdrawn.

Corrections to Previous Amendment

The Examiner has asserted that Applicant has amended claim 1 so that it is no longer directed towards the invention/species originally acted on. Specifically, the Examiner points out that, in the 5/28/03 response to the Examiner's 8/07/02 restriction requirement, Applicant elected a "flat", rather than a "triangular" distribution for the self induced fission rate. The word "triangular" has been removed from claim 1.

The Examiner further contends that the amendments to claim 1 and 27 also include "a new independent and distinct species wherein a probability distribution is also assigned to the spontaneous fission rate." However, Applicant respectfully submits that the spontaneous fission rate is not a new species, given that it was previously presented, for example, in claim 16. Furthermore, a flat probability distribution for the spontaneous fission rate is also not new (see, for example, claims 16 and 21.)

Missing References from IDS Filed 2/13/02

Please find enclosed the references listed as 2-4 on the IDS filed on 2/13/02.

Rejections under 35 U.S.C. 103

The Examiner has rejected claims 1-5, 10-12, 27-33 under 35 U.S.C. 103 as lacking novelty over any of Wachter et al; Caldwell et al, (U.S. patent number 4483816); or Untermeyer, (U.S. patent number 3786256). These rejections are respectfully traversed.

As the introduction to the application acknowledges on page 2, last paragraph, techniques for establishing a neutron mass present in a sample, using multiplicity counting exist. However, in all prior art cases, one of two approaches needs to be taken and each has its own problems.

Firstly, it is possible, in relation to at least one variable out of spontaneous fission rate, self induced fission rate, detection efficiency and the λ_n reaction rate to make assumptions and set that variable at a particular value. The problem with this approach is that the extent to which

the assumption is applicable to a measurement is absolutely fundamental to the accuracy of the result. Issues affecting the applicability of the assumptions are detailed on page 3, paragraph 3 of the application.

The only other prior art approach is to measure enough variables relating to the neutron emissions to match the number of unknowns and so render the system solvable. In the case of neutron coincidence counting that means measuring four count rates, namely single, double, triple and quadruple. The need to measure quadruple count rates causes a massive problem. For there to be any degree of accuracy to the process, the quadruplet count must be of a statistically significant level. However, the detection of doubles is rarer than singles (as both neutrons must reach the detector) and the detection of triples is rarer still, with the detection of quadruples extremely rare indeed. For high level emitting sources, a meaningful quadruple count rate would take a very long time to obtain (days). For lower levels of emission it may never be possible to obtain a valid measurement.

The present invention addresses this issue in a fundamentally different way to the prior approach of fixing one or more of the variables or the need to achieve four count rates. Instead the value of all the variables is free within the bounds of a probability distribution in each case, and yet the method achieves a solution using only three count rates. In the preferred form, certain constraints are put on the value a particular variable can have based on sensible and totally applicable considerations (for instance the detection efficiency must be between 0% and 100%, 0 and 1). Between the constraints the frequency of occurrence of a particular value for the variable is set by a probability distribution. Some preferred forms for such distributions are suggested but the methodology can function with any probability distribution assigned to a variable.

In respect of a measured single count rate value a probability distribution is defined around it. The likelihood of any other count rate value relative to it can be obtained by taking the probability distribution function, pdf, (x axis) for that value (y axis). This enables a pdf for a predicted count rate to be obtained in respect of a particular measured count rate. If the predicted count rate is close in value to the measured count rate then a high pdf will arise. This would suggest that the manner in which the predicted count rate was generated is an accurate match for the situation being measured. If the predicted count rate is well away from the measured count rate then a very low pdf will arise. This would suggest that the manner in which the predicted count rate was generated was a poor match for the situation being measured.

A pdf in respect of predicted count rates for the double and triple count rates is similarly obtained from their distribution about the measured count rate.

In respect of the four variables a value (potentially randomly selected or selected based on an estimate) is selected for each and a pdf value obtained for each by reading it off according to their assigned probability distribution. Using the equations set out in the application these values for the variable also enable the equations to be solved and give rise to predicted count rates. The likelihood, pdf, for the predicted count rate can be read off the distribution for that count rate as referred to above.

The result is a pdf for each of the four variables, according to the value given to them, and a pdf for each of the three count rates, according to the predicted count rate. By multiplying all 7 pdf's together a "value of the product of all of the probability distribution factors" is obtained. This overall value could be considered a measure of the likelihood of the observed results given those values for the variables. The overall value is important in considering the fit in relation to all the variables. A situation may give a good fit for one variable, but a poor fit for another and this needs to be taken into account.

Based on the calculations, adjustments to one or more of the four variable values are made and then used in the next iteration of the process. After many iterations a "value of the product of all of the probability distribution factors" is obtained which is high in value. In effect the values for the spontaneous fission rate, self induced fission rate, detection efficiency and the $\bar{\nu}$,n reaction rate are themselves likely and so have a high pdf and they also give rise to predicted count rates which are close to or equal to the observed count rates and so also give rise to high pdf's too.

These particular values for the variables are thus deemed the appropriate ones to use in the calculation of the neutron mass.

It is respectfully submitted that the concept of a probability distribution for the variables is entirely lacking in the prior art. All three of the prior art documents cited fall with one of the two prior art approaches discussed above.

Caldwell

In Caldwell et al, US 4483816, both active investigation (subjecting the sample to neutrons from a generator) and passive investigation (considering neutrons arising naturally from the sample) are used. The present invention relies solely on passive investigation. The part of Caldwell describing the passive investigations, column 3, lines 48-64, makes it clear that Caldwell measures single, double, triple and quadruple coincidences - *"..also coincidence neutron emission up to four simultaneous neutrons."* The reason for this essential need to measure four neutron coincidence count rates is stated at column 6, lines 15-19, where it states *"Clearly an unlimited number of unknowns in such a mixture cannot be uniquely assayed. For the four principle isotopes present in transuranic waste, the number of events of spontaneous emission of up to four neutrons must be measured."* This is one of the two prior art approaches acknowledged in the introduction to the present application. One approach is to assume the value of one of the variables and hope the assumption is accurate. The other, and the one Caldwell says is essential for its operation, is to measure single, double, triple and quadruple count rates. This means that Caldwell requires very large measurement times to provide accurate results and hence gives rise to substantial problems in practice.

The requirement of Caldwell to measure four neutron count rates means that the technique of the present invention is not used in any way by Caldwell. With reference to claim 27, for instance, Caldwell does not provide for:

a probability distribution is assigned to each of the spontaneous fission rate, the self induced fission rate, the detection efficiency and the γ, n reaction rate and each of the counting rates -

Caldwell uses the measured values for the count rates in absolute terms and calculates an absolute value for each of the other variables; and so cannot employ a method in which there is provided *a probability distribution factor for any given value*; and does not involve any form of optimization and certainly not one in which *the value of the product of all the probability distribution factors is increased to give an optimized solution* and so provide an optimized value for the spontaneous fission rate which can then be used to give an optimized measure of the mass of the neutron source.

Similar distinctions apply in relation to claim 13 and in relation to claim 1 (which is also further distinguished by the optimal shape of probability distribution used for each variable).

The present invention is a significant improvement in terms of operational speed; as the need for quadruple counting is avoided. Furthermore, the floating nature of the variables in the present invention enable a wider range of different waste types to be assayed without problem. Caldwell, by its own admission at column 6, lines 21-29, acknowledges that its method *"requires a priori information that the aforementioned isotopes are present with only minor concentrations of others. If this is not true, and a different set of isotopes is present, then the algorithms to be described below will not give correct results..."*

The probability distributions assigned to the variables and count rates in the present invention should not be seen as in anyway the same as the "emitted neutron multiplicity distribution" referred to in Caldwell. As is clear from Caldwell at column 6, lines 38-42 and column 6, lines 14, these refer to the single to double to triple to quadruple count rate ratios observed for different isotopes, the ratios being different for different isotopes. They in no way refer to a range of values that a variable can have in the calculations of the present invention. Further confirmation as to the different nature of this distribution can be found in Untermeyer at column 7, lines 4-10 where the differences for different isotopes are tabulated.

The remainder of Caldwell is concerned with the use of active investigation to determine other properties of the sample and is unrelated to the present invention.

Accordingly, is respectfully submitted that the present invention is new and inventive over Caldwell.

Untermeyer

As far as the relevance of Untermeyer, US3786256, to the present invention is concerned, the teaching is very similar to that given by Caldwell. Untermeyer uses a source to actively interrogate a fuel rod. No passive measurements of the type used in the present invention are provided. The neutrons arising from the active measurements are, however, subjected to coincidence counting. As with Caldwell, Untermeyer makes it clear that four different count rates are needed for the technique to generate a result. This position is stated at column 6, lines 17-22 and column 6, lines 43-45 where it is stated *"This method depends upon the yield of neutrons per fission for each isotope and particularly on the varying probabilities of a fission event in a particular isotope emitting one or two or three or four coincident neutrons."* and *"This counter 74 measures count rates proportional to the number of single, double, triple or quadruple neutron coincidences."* respectively. As a result this piece of prior art does not

change the patentability of the presently claimed invention. The same patentable differences as identified above in relation to Caldwell apply.

Thus, it is respectfully submitted that the present invention is new and inventive over Untermeyer. Furthermore, any combination of Caldwell and Untermeyer would be no closer to the present invention than those documents are separately.

Wachter

Wachter et al provides a teaching which takes the other of the prior art approaches. In this case, single, double and triple counts are taken. However, because the use of three variables does not allow the solution of a problem with four unknowns in it (a fundamental principle of algebra) assumptions are made instead. On page 31 there is reference to a "*the absolute efficiency of the counter is 8% for fission neutrons*". This is an assumption, as efficiency of detection is not constant in practice; a position acknowledged further down the page where attempts are made to correct for "*detector efficiency drift*". The assumption on detection efficiency then allows Wachter to refer to establishing the other unknowns, namely "*sample mass, sample multiplication, and the ratio of (\bar{v} ,n) to spontaneous fission neutrons*". Thus, just as in the prior art approach acknowledged in the introduction to the present application, by making an assumption in respect of one of spontaneous fission rate, self induced fission rate, detection efficiency and the \bar{v} ,n reaction rate, the overall mathematics can be solved. Even within Wachter there is a clear acknowledgement that the use of such assumptions means that the approach does not work in cases away from the standard. On page 31 it is stated "*Not included in Table I are measurements of two PF_4 cans ($\bar{v}=100$) that did not give correct assays. The multiple scattering correction is not sufficiently understood to assay samples with such high (\bar{v} ,n) yields*". Wachter is not relevant to the presently claimed invention. The present invention solves and claims an entirely different approach in which all four variables are floating and no assumptions are required.

Accordingly, it is respectfully submitted that the present invention is new and inventive over Wachter. No combination of Wachter's teaching with any of the other documents changes this position.

Combining any of the above with each other or with either Wyllie or Baron does not change the basic position with respect to any of these three documents.

Wyllie

Wyllie (*Appl. Radiat. Isot.* Vol. 38, No. 5, pp 385-389, 1987) does not detail the operation of the calculations involved in determining the mass of neutron emitting material present. As such it does not indicate whether it follows the prior art approach of an assumption on one of the variables or the use of four separate counts. There is certainly no suggestion of the calculation approach taken in the presently claimed invention.

Wyllie is concerned with correcting the double count observed to the double count that actually occurred. It does so by correcting for those events which would have occurred in a detector during the dead time for a detector. After a detector registers an event, there is a period of time (dead time) during which it is insensitive to other events. Hence an event could have occurred but not registered and hence not formed part of the double count rate. the teaching of Wyllie does not alter the position with regard to the patentability of the presently claimed invention.

Thus, it is clear that Wyllie is concerned with a different issue than that of the present invention and does not overcome the deficiencies of Caldwell and/or Untermeyer and/or Wachter.

Baron

Baron (*International Conference on Nondestructive Evaluation in the Nuclear Industry*, LA-UR 78-1444, pp 1-21, 1978) page 2, bottom of page, is concerned with a very basic form of neutron coincidence counting. It notes that various factors impact upon the accuracy of measurements of the mass of neutron material present. In presenting its methodology it states frequently that various assumptions are made. This document is consistent with that prior art approach, therefore. Thus, it is respectfully submitted that Baron, like Wyllie, does not overcome the deficiencies of the primary references.

Rejections under 35 U.S.C. 112 and 35 U.S.C. 101

The "enablement" objections are now addressed in the paragraph order used by the Examiner in section 4 of the office action.

Paragraph 2 - With regard to the term "the spontaneous fission rate is associated with the neutron source mass" this would appear to have occurred in claim 13 and claim 33. Claim 33

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has now been deleted and claim 13 has been amended to refer to "linked to" instead; this phrase has already been used in claim 1 and claim 27. The objection to this language itself is dealt with in relation to paragraph 5 below.

Paragraph 3 – The Examiner has stated that there is no adequate description nor enabling disclosure of how and in what manner the singles doubles and triples are used. Applicants are unclear as to the Examiner's basis for this rejection. By way of explanation, the present invention is primarily concerned with establishing the mass of neutron emitting material present within a sample as accurately as possible. **This quantity is a useful indication in itself.** To obtain it the method includes measuring "singles, doubles and triples" counts. At no stage are these measurements used to determine the isotopic make up of the waste material. This is not a requirement in relation to the determination of the mass of neutron emitting material present as performed by the present invention.

Paragraph 4 – The specification has been amended to address Examiner's concerns regarding the "correction factor" on page 5. Deleting the sentences which refer to the page 5 correction factor serves to avoid any confusion between correction for this issue and the page 10+ form of correction.

This page 10+ form of correction is concerned with the variation/correction applied to one or more of the values for the four variables (spontaneous fission rate, self-induced fission rate, detection efficiency and V_n reaction rate) between one iteration and the next of the product of all of the probability distribution factors. This is made clear from the passage at page 9, paragraph 5. Pages 10 through 12 expand upon the concept of the variation/correction in terms of a correction vector and its form, calculation and optimization. This is an approach and methodology which is fully understandable to a person skilled in the art given the content of the present application.

The "constant factor" referred to on page 12 is further expanded upon at page 25. The variation/correction of one or more of the variables seeks to move the predicted position into agreement with the observed position. The correction vector used to do this may sometimes overestimate the distance it should move in an iteration (thereby going straight past a better solution) or may underestimate the distance it should move in an iteration (thereby taking an inordinately long time to reach the better solution). To check against this, as well as the

suggested correction vector iteration, an iteration which is less than this and an iteration which is significantly greater are also checked. The relative positions are half the iteration and 32 times the iteration, in the specific form referred to in the text of the application. However, other constant factors could be used, such as 1/4 and 20 times etc. Again it is believed that the term "constant factor" and its use are fully enabled by the application.

Paragraph 5 - The method of the present invention enables the "spontaneous fission rate" to be obtained in an accurate manner across a wider range of conditions than is possible using the prior art approach. This spontaneous fission rate can be used as the start point in a simple calculation to give the mass of the neutron source and hence the claim language which "linked to the mass of the neutron source" is intended to refer to. This is an established calculation well known in the art. The present invention is concerned with the new and inventive way in which the spontaneous fission rate is reached.

Paragraph 6 - The references to "normal", "flat" and "triangular" distribution are references to standard forms of distribution well known in the fields of statistics and mathematics and well known to those applying such techniques. They refer to the frequency of occurrence against value for the variable in question (such as count rate). Thus a flat distribution means the frequency of occurrence is constant across all values; a triangular distribution means the frequency of occurrence increases in a linear manner from a first value to the most frequently occurring value and then decreases again in a linear manner to zero occurrence at a further value and so on. Whilst there are preferred distributions for the various variables involved in the present invention, other distribution forms are known and can well be used too.

It is respectfully submitted that the application is fully enabling to a skilled person as they are well aware as to the meaning of these terms.

Paragraph 7 - Just as the skilled person is well aware of the different types of probability distribution referred to in the response on paragraph 6, so the skilled person is aware from the fields of statistics and mathematics that such distributions can be symmetrical or skewed. In the case of a symmetrical distribution the frequency varies in an equivalent manner either side of their most frequently occurring value and the most frequently occurring arises at the mid point of the range of values. In the case of a skewed distribution the most frequently occurring value is not at the mid value of the range, but rather is to one side thereof.

In view of the foregoing, it is respectfully submitted that the application is fully enabling to a skilled person, as they are well aware as to the meaning of these terms.

Paragraph 8 - On pages 7 to 9 and again on pages 20 to 21 the form and constraints preferred for the distributions in respect of the variables are described. These are clearly and unambiguously defined and can thus readily be used by the skilled person. The manner in which such preferred features are defined is not essential to the invention, merely that they are provided. In any event, the application and/or a skilled persons knowledge would provide sufficient guidance on how to obtain such figures. In relation to detector efficiency, the distribution is set to range between zero efficiency and maximum efficiency, 1. For fission rate distribution, this is present and so it must range from zero upwards in value. For multiplication, again this is present and so must multiplication by a figure of 1 or greater is needed.

The application is fully enabling to a skilled person as the application provides full guidance and figures for the constraints on the distributions.

Paragraph 9 - Whilst each formula is not accompanied by a full listing of the symbols referred to in it, there is, Applicants believe, a full listing of the meaning of all the symbols with the application as a whole. By way of and example, see pages 20 and 21 of the application.

Paragraph 10 - The information referred to on page 9, line 2 onwards can arise from a variety of sources. Firstly, the type of gamma spectrometry investigation referred to in the preceding sentence can be used to provide information on the isotopes present by analyzing gamma emissions which are at an energy characteristic of a particular isotope. Secondly, written records on the material up for investigation or prior knowledge about the types of material produced by a plant can assist. These may confirm the likelihood of neutron emitters being in a particular form and/or confirm certain forms as not being possible. They may indicate the nature of the materials accompanying the neutron emitters, such as moderators. The information may be applied in a variety of ways. Some such ways are illustrated in paragraph 4 of page 8, where the self-induced fission rate is constrained according to the anticipated plutonium content level, the detector efficiency is constrained according to the anticipated moderating materials etc. Again Applicants believe the manner in which this part of the technique is clear upon reconsideration.

Paragraph 11 - As far as the manner and steps used to obtain an optimized or maximized solution to the inventions method is concerned, page 9 of the application, much of the approach taken is apparent from the above discussion of the invention relative to the prior art. In basic

terms the value of the product of all the probability distribution factors is at its highest when the predicted position is a close model for the observed position which gave rise to the actual count rates. Gradual variation of the values of the variables is used to vary the probability distribution factors towards the optimized solution. The application contains substantial amounts of detail on the approach taken and is quite clear.

Paragraph 12 - The error estimates provided on page 12 onwards and on page 26 onwards are optional features for the present invention. Details of their use are not needed to perform the basic claimed invention. In any event, the sequence of equations and explanation provided on pages 26 to 28 in particular are sufficient to enable a skilled person to perform the analysis of the errors applying. The mathematics may be complicated, but the starting point and working of the mathematical method is detailed. Again Applicants do not believe the application to be insufficient.

Paragraph 13 - The inquiry as to how the methodology of claim 1 reveals the isotopic form of the sample seems to be based on a mistaken impression as to the characteristic the invention is seeking to determine. The invention's method does not seek to state there is x of isotope 1, y of isotope 2 and z of isotope 3. **The invention seeks to determine a mass of the neutron source.**

Paragraph 14 - The "value of the product of all the probability distribution factors" is not increased by a given quantity or step. It is not the value which is varied and the effect on the probability distribution factors considered. The invention works in the opposite direction and considers different values for the one or more variables (the value being within the permitted range for that variable) and considers their impact on "the value of the product of all the probability distribution factors". In very simplistic terms, a change in value of a variable which increases "the value of the product of all the probability distribution factors" is seen as working towards a better determination of the neutron mass present, whereas a change in the value of a variable which decreases "the value of the product of all the probability distribution factors" is seen as heading away from a better determination of the neutron mass present.

Through a large number of iterations, changing one or more of the values of the various variables, "the value of the product of all the probability distribution factors" is maximized as described in the response on paragraph 11 above.

Paragraph 15 - Again Applicants believe that the application as a whole provides extensive guidance on just these issues. Pages 20 and 21 detail boundaries/constraints for these variables.

They could simply be varied by taking an alternative value within that range for use in the next iteration of the calculation of the product of all of the probability distributions. However, the application provides a far more efficient and effective method for establishing the size and direction from the variation/correction. The process of pages 22 onwards applies in this regard. The application provides significant detail on the correction vector approach which provides the extent and direction of each variation of each variable. Repeated iterations of this approach lead to the maximized solution and hence the result of the method.

Paragraph 16 - A number of techniques exist which a skilled person would be well aware of which enable a determination as to whether a count is a single, a double, a triple or a greater value to be determined. In basic terms, and as detailed on pages 1 and 2 of the application *"Signals detected within a certain time window are taken as being indicative of a pair, rather than a single neutron, which can neither be attributed to the background or the plutonium with any certainty."* This manner of establishing which events count as doubles, triples etc is reiterated at page 5, paragraph 5 and again on page 18. Again the invention is fully enabled by the application.

Contrary to the Examiner's suggestion, it is respectfully submitted that the method outlined in the claims constitutes a series of steps to be performed and not a result to be achieved. The steps are concrete in their nature and advance the investigation from a position of raw information to an accurate result.

Rejections under 35 U.S.C. 101

In relation to the majority of points, the discussion above addresses the Examiners' objection. The technique is clearly workable and provides the required information. Furthermore, it does so in a method which is completely novel and inventive. The technique may be complex in its detail, but that does not detract from the patentability of the underlying concept.

Rejections under 35 U.S.C. 112, 2nd paragraph

Claims 1, 13, and 27 have been amended to ensure that all of the variables which need to be considered as having probability distributions assigned to them are mentioned in the claims.

Claims 10, 12, 30 and 31 have been amended in order to address Examiner's objection to "vague, indefinite, and incomplete" terms such as "preferably" and relative terms that "can be

given no definite meaning." Claims 4-5 have been amended to include definitions for each of the variables and symbols in the equations,

Claim 28 has been amended to provide antecedence.

Applicants believe that all pending claims are allowable and respectfully requests a Notice of Allowance for this application from the Examiner. Should the Examiner believe that a telephone conference would expedite the prosecution of this application, the undersigned can be reached at the telephone number set out below.

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